BELLCOMM, INC.
955 L'ENFANT PLAZA NORTH, S.W. WASHINGTON, D. C. 20024

B71 03025

SUBJECT: Apollo 15 Translunar and Lunar Orbit Aborts for the Nominal Launch - 7/26/71
Case 310

DATE: March 7, 1971

FROM: M. K. Baker

ABSTRACT

Translunar SM RCS aborts to nominal earth entry are possible with the docked spacecraft until approximately 60 hours after TLI for the nominal Apollo 15 mission, launched on July 26, 1971.

Return to earth from lunar orbit is possible using the LM descent propulsion any time prior to powered descent.

The maximum return-to-earth time from a point on the translunar trajectory, assuming a LM descent propulsion abort maneuver, is approximately 110 hours. This occurs for an abort at 24 hours post TLI. If a ΔV of 8000 fps is employed for aborts using the DPS+SPS, the maximum return time is only 44 hours for an abort at 63.5 hours post TLI.

Abort ΔV's are generally lower for the Apollo 15 mission than for Apollo 14.

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MEMORANDUM FOR FILE

Two types of translunar abort trajectories are considered for the Hadley mission to be launched on July 26, 1971 with an 80° azimuth: minimum-ΔV and minimum-return-time. Minimum-ΔV abort trajectories are designed from any point on the nominal trajectory such that a minimum expenditure of propellants places the spacecraft on an earth return trajectory which satisfies the reentry requirements. Minimum-return-time abort trajectories are computed such that the time from the abort point to reentry is minimized for some maximum ΔV available. In addition, the return-to-earth ΔV costs from lunar orbit have been determined.

I. Translunar Aborts

While previous Apollo lunar missions were nominally on free return trajectories for all or part of the translunar coast, the Apollo 15 translunar trajectory will not return to earth without a propulsive maneuver. However, the trajectory has been designed with two constraints: 1) RCS aborts are possible until at least five hours after TLI; 2) an abort maneuver at pericynthian plus two hours is within the capability of the LM descent propulsion system (DPS) to place the spacecraft on a safe earth return trajectory. Thus, the question of contingency earth returns is of particular interest throughout the Apollo 15 translunar trajectory.

A. Minimum-ΔV Aborts

Three types of minimum-ΔV aborts to achieve a safe return are considered:

Corrected

1. Maneuver to place the spacecraft on a trajectory which returns to an unconstrained earth landing point.

2. Maneuver to place the spacecraft on a trajectory which returns to an unconstrained earth landing point plus a second maneuver at two hours after pericynthian to assure landing in the midpacific recovery area (150°W-170°W).

3. Maintain the nominal trajectory through pericynthian and then make a maneuver to place the spacecraft on a trajectory that lands in the midpacific recovery area.

The first case above represents the minimum abort ΔV possible since constraining the return trajectory to landing in a specified area will usually result in additional ΔV cost.

Figure 1 illustrates the ΔV costs for these three strategies for minimum-ΔV aborts.

The cost of the abort maneuver increases as the elapsed time from translunar injection (TLI) increases. The splash-down points of the unrestricted-landing-area trajectories vary from 78°W to 70°E. In the region of 3.5 to 5 hours after TLI a minimun ΔV abort would place the landing point on Africa. In the region from MSI entrance to pericynthian (63 to 75 hours after TLI) any minimum-ΔV abort would place the landing point on South America. However, the landing point could be shifted to produce a water landing by subsequent trajectory corrections, by expending more ΔV than required by the minimum maneuver, or simply by delaying the maneuver.

Minimum-ΔV aborts from the Apollo 15 translunar trajectory are within the SM RCS capability of 75 fps for about 60 hours after TLI. The RCS ΔV capability includes an allowance for post-abort course corrections and attitude control.(1) The 75 fps capability represents about 75 percent of the total RCS usable propellant. The DPS ΔV available on the translunar leg is $\sim$2000 fps. Retaining a 100 fps midcourse allowance, this ΔV provides return-to-earth capability beyond 90 hours (MSI exit) after TLI for the docked CSM+LM configuration for both mid-pacific and unrestricted landing points.

B. Minimum-Time Aborts

In the event of an emergency which requires the fastest safe return to earth, there are several abort modes available. All are dependent on the available propulsion systems and the time when the minimum-time return is initiated. Two strategies for fast earth returns for various ΔV capabilities are considered:

1. A direct return to earth without going around the moon.

2. An immediate minimum ΔV maneuver to put the spacecraft on a circumlunar return trajectory and a second maneuver executed two hours after pericynthian to speed up the vehicle.

Splashdown point is unrestricted in both cases.

The maximum ΔV capabilities of the various propulsion systems that might be available for an abort are summarized in Table I. These ΔV capabilities include in usuable propellant the 3σ dispersion propellant currently allotted for the DPS, APS and SPS. Abort allowances are also included in usable propellant of the DPS and APS. The cases plotted in Figure 2, 2000 fps (DPS), 5000 fps (SPS) and 8000 fps (DPS+SPS) roughly correspond to cases 1, 2 and 3, respectively in Table 1.

Examination of Figure 2 shows that the minimum return time for direct aborts increases as a function of time elapsed from TLI while return time decreases for circumlunar aborts. Thus there is a point at which the return time is the same for the circumlunar and the direct abort. This point is designated in what follows as the critical point.

The critical point for the DPS abort case occurs at 24 hours after TLI with a corresponding return-to-earth time of 110 hours. For the SPS case the critical point occurs at 52 hours after TLI with a return-to-earth time of 64 hours. The DPS+SPS case yields a critical point just inside the lunar sphere of influence at 64 hours after TLI and provides a maximum return time of 44 hours. All return trajectories considered have a reentry velocity less than the 37,500 fps maximum established in the RTCC.

Data in Figure 2 also indicate the various times when a direct abort would land at the Midpacific line (165°W) and the Atlantic Ocean line (25°W). Since earth landing points for the minimum time returns sweep across the major landmasses of Australia, Africa and South America, in some cases, to avoid land landings, a slightly longer than minimum return time must be employed or the abort must be delayed.

II. Lunar Orbit Aborts

The ΔV costs of aborts to earth entry from lunar orbit are somewhat more expensive than aborts from the translunar coast. The energy expended during LOI must be expended again to depart from the vicinity of the moon.

Figure 3 illustrates the return-to-earth ΔV cost (or TEI cost) as a function of time in lunar orbit. The spacecraft does LOI into a 60x170 nm orbit and remains in that orbit for two revolutions. DOI places the spacecraft into a 60x8 nm orbit where it stays until after separation. Between LOI and DOI the TEI cost is lowest. After the DOI maneuver the ΔV cost to get out of orbit increases roughly by an amount equal to the DOI maneuver or 200 fps. At the same time, because of the reduction in total spacecraft weight by the propellant expended for DOI, the DPS capability increases by 100 fps. Return to earth from lunar orbit is possible using the DPS any time prior to powered descent. Corresponding to each revolution in lunar orbit, there are usually two different TEI ΔV costs depending on the transearth flight time. For this mission the faster transearth coasts cost more ΔV. The ΔV capabilities for the various propulsion systems after LOI and after DOI are given in Table I.

Summary

The minimum-ΔV abort capability and the minimum-return-time capability represent the extremes of return-to-earth times available during the mission. In the event of a contingency during a mission a continuous range of return-to-earth times between these boundaries would be available. The specific choice would have to depend on real-time factors such as the choice of landing area, condition of the spacecraft systems and the condition of the crew.

Translunar SM RCS aborts are possible with the docked spacecraft until approximately 60 hours after TLI. Return to earth from lunar orbit is possible using the DPS any time prior to powered descent. The maximum return-to-earth time from a point on the translunar trajectory using the DPS is approximately 110 hours. This occurs for an abort at 24 hours post TLI. If a ΔV of 8000 fps is employed for aborts using the DPS+SPS, the maximum return time is only 44 hours.

M. K. Baker

2013-MKB-slr M. K. Baker

Attachments

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REFERENCE

1. Stern, R. J., "Preliminary Evaluation of SM/RCS Capability to Abort to Earth Entry from the Relaxed Free Return Profile," Bellcomm Memorandum for File B70 09084, Case 310, September 30, 1970.

TABLE I

MAXIMUM ΔV AVAILABLE FOR HADLEY MISSION

LAUNCH JULY 26, 1971*

Option	Source of Propulsion	Post Abort Configuration	ΔV		
			Post TLI	Post LOI	Post DOI
1	DPS	CSM+LM	2030	2860	2960
2	SPS	CSM+LM	5000	2040	1850
3	DPS+SPS	CSM+LM	8660	4700	5560
4	DPS+SPS	CSM	11330	7180	6960
5	SPS	CSM	9300	4320	4000
6	SPS+DPS	CM+LM	9920	6950	6760
7	DPS	CM+LM	4910	4910	4910
8	DPS+APS	CSM+A/S	2710	3920	4070
9	SM/RCS	CSM+LM	75		
10	SM/RCS	CSM	130		

*Spacecraft weights and propellant available were taken from the January 15, 1971 MSC Apollo Spacecraft Weight Status Summary.

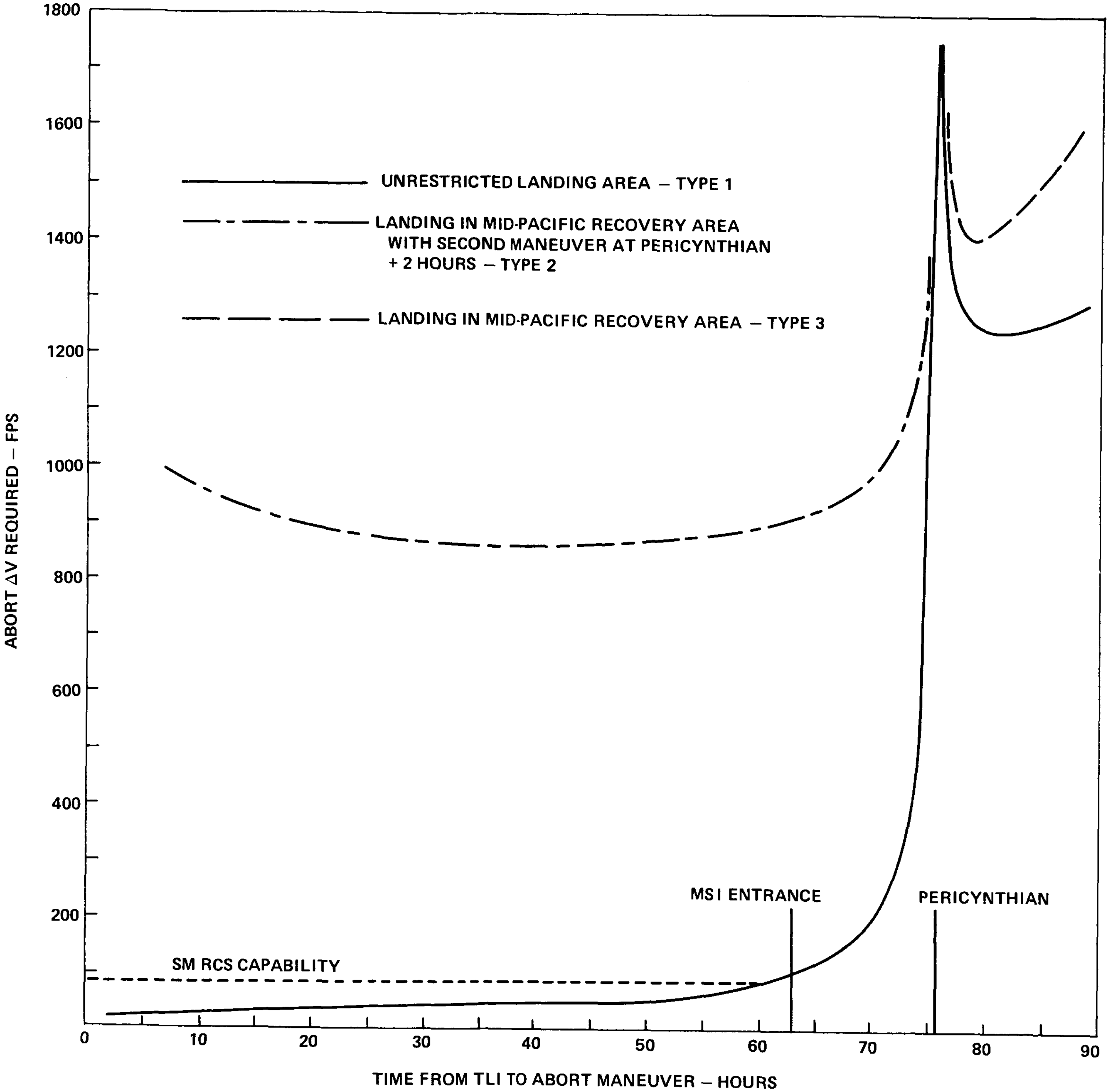

FIGURE 1 - APOLLO 15 MINIMUM ΔV ABORT REQUIREMENTS
LAUNCH DATE – JULY 26, 1971

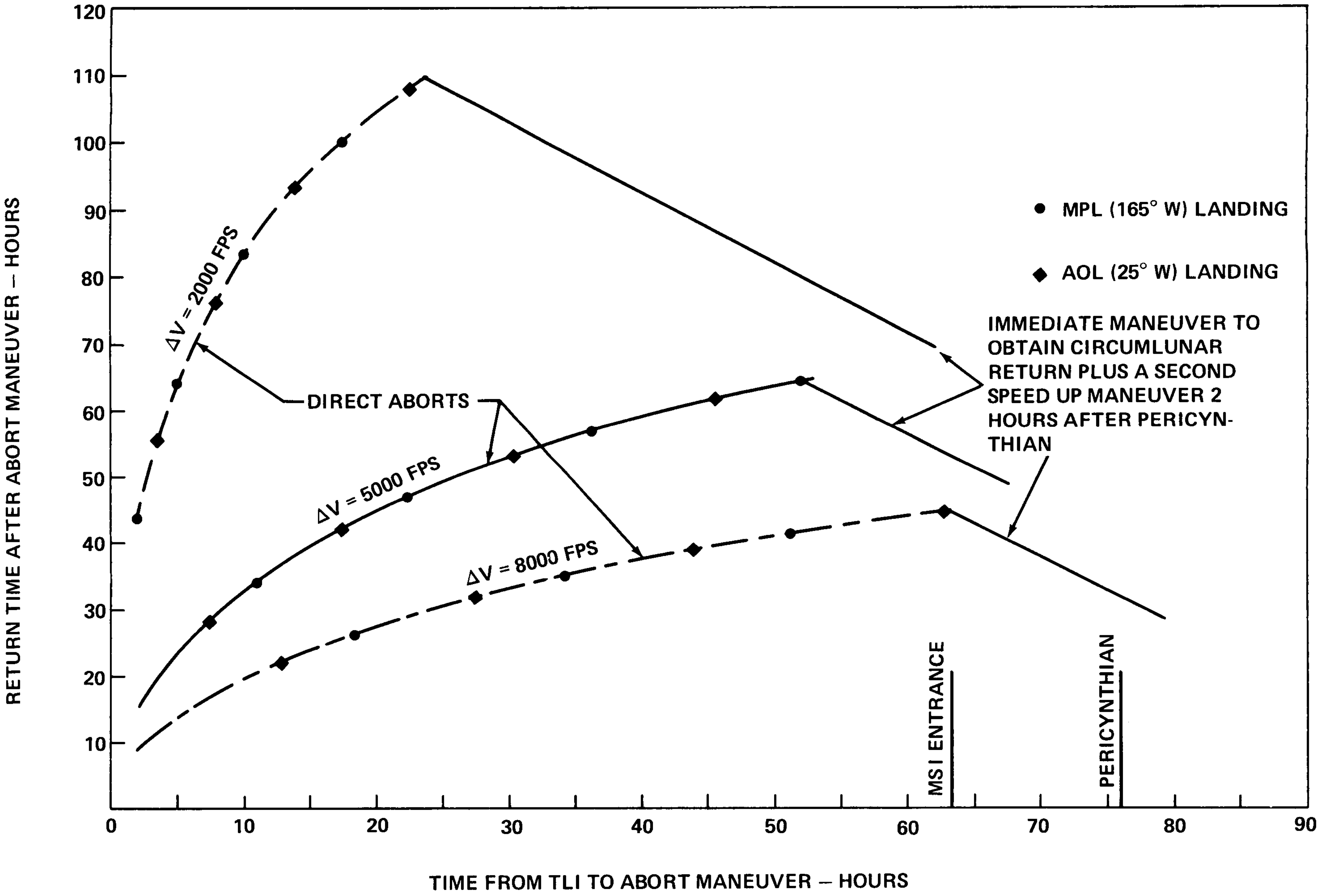

FIGURE 2 - APOLLO 15 MINIMUM RETURN TO EARTH TIMES FOR TRANSLUNAR ABORTS
LAUNCH DATE – JULY 26, 1971

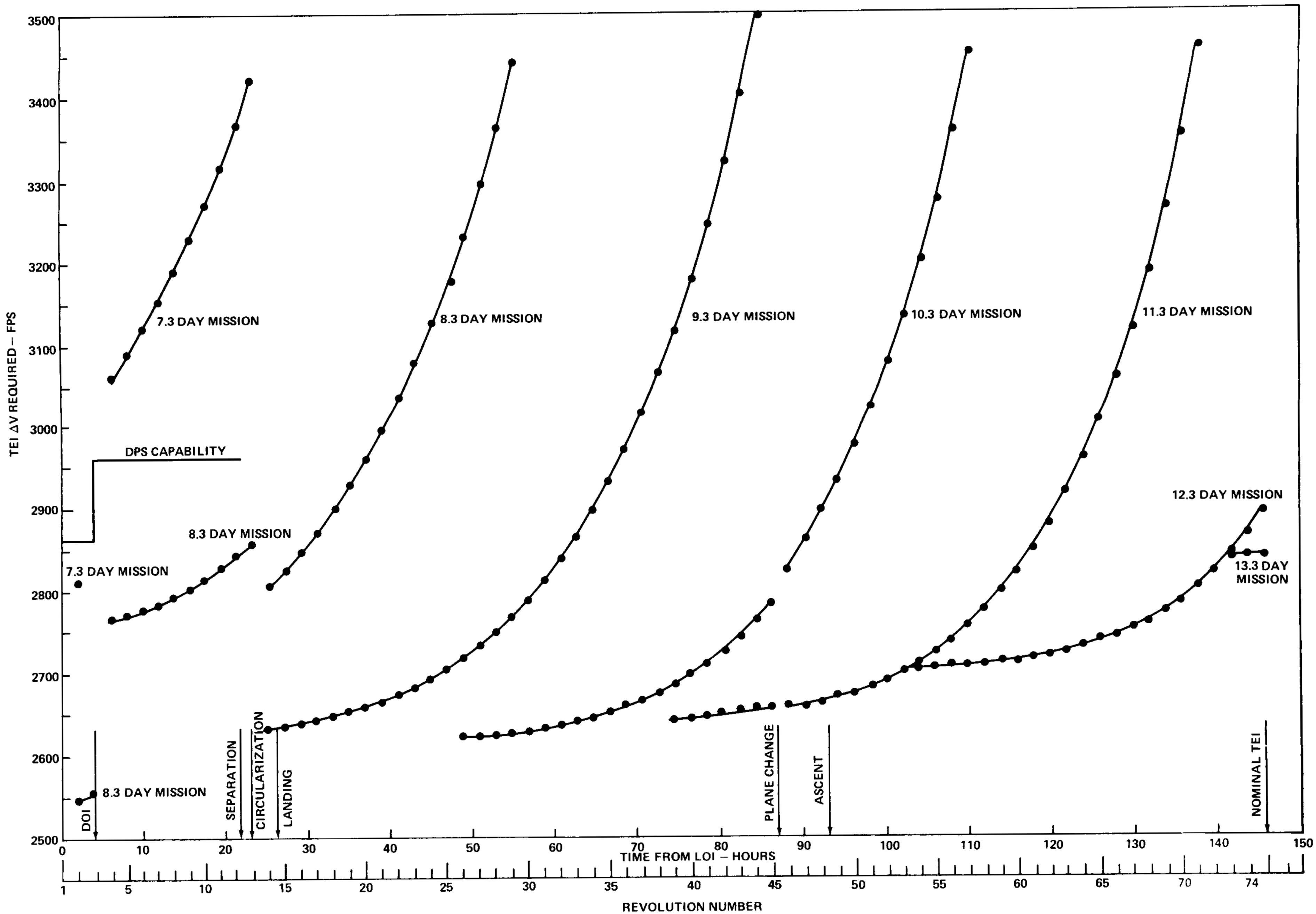

FIGURE 3 - APOLLO 15 RETURN TO EARTH REQUIREMENTS FROM LUNAR ORBIT
LAUNCH DATE – JULY 26, 1971

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